User Guide for

FEB_L040

Evaluation Board

Universal Input 3.5W LED Ballast Controller

Featured Fairchild Product: FLS3217M

Direct questions or comments about this evaluation board to: "Worldwide Direct Support"

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This user guide supports the evaluation kit for the FLS3217M. It should be used in conjunction with the FLS3217M datasheet as well as Fairchild's application notes and technical support team. Please visit Fairchild's website at www.fairchildsemi.com.

1. Introduction

This document describes the proposed solution for a universal line voltage LED ballast using the FLS3217M buckboost controller. The input voltage range is $90V_{RMS}$ – $265V_{RMS}$ and there is one DC output with a constant current of 100mA at $35V_{MAX}$. This document contains a general description of the FLS3217M, the power supply specification, schematic, bill of materials, and typical operating characteristics.

1.1. General Description

The FLS3217M is an active Power Factor Correction (PFC) controller using single-stage flyback topology. Primary-side regulation and single-stage topology minimize cost and reduce external components, such as input bulk capacitor and feedback circuitry. To improve power factor and THD, constant on-time control is utilized with an internal error amplifier and a low-bandwidth compensator. Precise constant-current control regulates accurate output current, independent of input voltage and output voltage. Operating frequency is proportionally changed by output voltage to guarantee Discontinuous Conduction Mode (DCM) operation with high efficiency and simple design. FLS3217M provides open-LED, short-LED, and over temperature protections.

1.2. Features

- Cost-Effective Solution without Input Bulk Capacitor or Feedback Circuitry
- Power Factor Correction (PFC)
- Integrated Power MOSFET
- Accurate Constant-Current (CC) Control: Independent Online Voltage, Output Voltage, and Magnetizing Inductance Variation
- Linear Frequency Control for Better Efficiency and Simple Design
- Open- / Short-LED Protection
- Cycle-by-Cycle Current Limiting
- Over-Temperature Protection with Auto Restart
- Low Startup Current: 20μA
- Low Operating Current: 5mA
- V_{DD} Over-Voltage Protection
- V_{DD} Under-Voltage Lockout (UVLO)

1.3. Internal Block Diagram

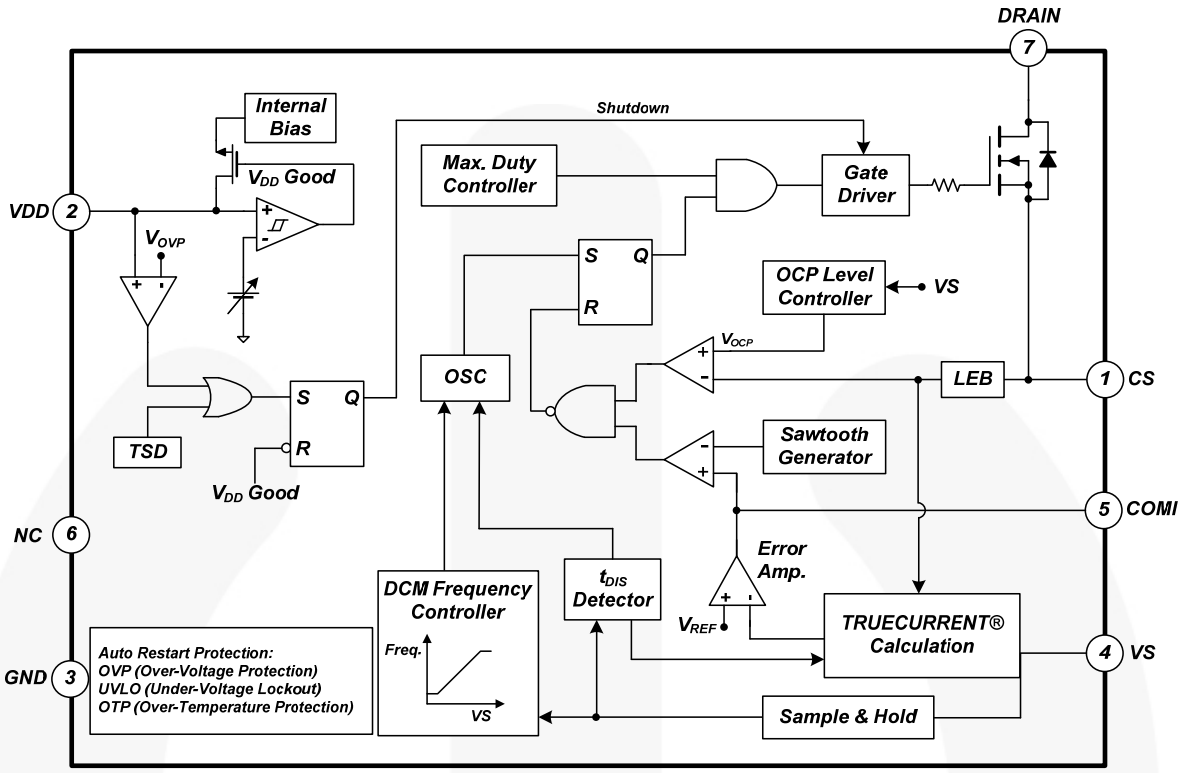

Figure 1. Block Diagram

2. Specifications for Evaluation Board

All data of the evaluation board was measured with the board enclosed in a case and external temperature around 25°C.

Table 1. Evaluation Board Specifications for LED Lighting Bulb

Description		Symbol	Value	Comments
Input	**Voltage**	$V_{IN.MIN}$	90V	Minimum Input Voltage
		$V_{IN.MAX}$	265V	Maximum Input Voltage
		$V_{IN.NOMINAL}$	110V / 220V	Nominal Input Voltage
	Frequency	f_{IN}	60Hz / 50Hz	Line Frequency
Output	**Voltage**	$V_{OUT.MIN}$	20V	Minimum Output Voltage
		$V_{OUT.MAX}$	38V	Maximum Output Voltage
		$V_{OUT.NOMINAL}$	35V	Nominal Output Voltage
	Current	$I_{OUT.NOMINAL}$	100mA	Nominal Output Current
		CC Deviation	< ±2.17%	Line Input Voltage Change: 90~265V_{AC}
			< ±2.22%	Output Voltage Change: 19.5~36.3V
Efficiency		Eff_{90VAC}	84.16%	Efficiency at 90V_{AC} Line Input Voltage
		Eff_{120VAC}	86.62%	Efficiency at 120V_{AC} Line Input Voltage
		Eff_{140VAC}	87.06%	Efficiency at 140V_{AC} Line Input Voltage
		Eff_{180VAC}	87.42%	Efficiency at 180V_{AC} Line Input Voltage
		Eff_{220VAC}	86.19%	Efficiency at 220V_{AC} Line Input Voltage
		Eff_{265VAC}	83.81%	Efficiency at 265V_{AC} Line Input Voltage
PF/THD		PF / THD_{90VAC}	0.997 / 21.03%	PF / THD at 90V_{AC} Line Input Voltage
		PF / THD_{120VAC}	0.990 / 23.81%	PF / THD at 120V_{AC} Line Input Voltage
		PF / THD_{140VAC}	0.986 / 24.85%	PF / THD at 140V_{AC} Line Input Voltage
		PF / THD_{180VAC}	0.973 / 25.74%	PF / THD at 180V_{AC} Line Input Voltage
		PF / THD_{220VAC}	0.934 / 28.05%	PF / THD at 220V_{AC} Line Input Voltage
		PF / THD_{265VAC}	0.918 / 29.78%	PF / THD at 265V_{AC} Line Input Voltage
Temperature	**FLS3217M**	$T_{FLS3217M}$	55.6ºC	Open-Frame Condition (T_A = 25ºC) FLS3217M Temperature
	Startup Resistor	T_{START}	55.3ºC	Primary MOSFET Temperature
	Freewheeling Rectifier	T_{DIODE}	47.4ºC	Secondary Diode Temperature
	Transformer	$T_{TRANSFORMER}$	51.3ºC	Transformer Temperature

2.1. Photographs of Evaluation Board

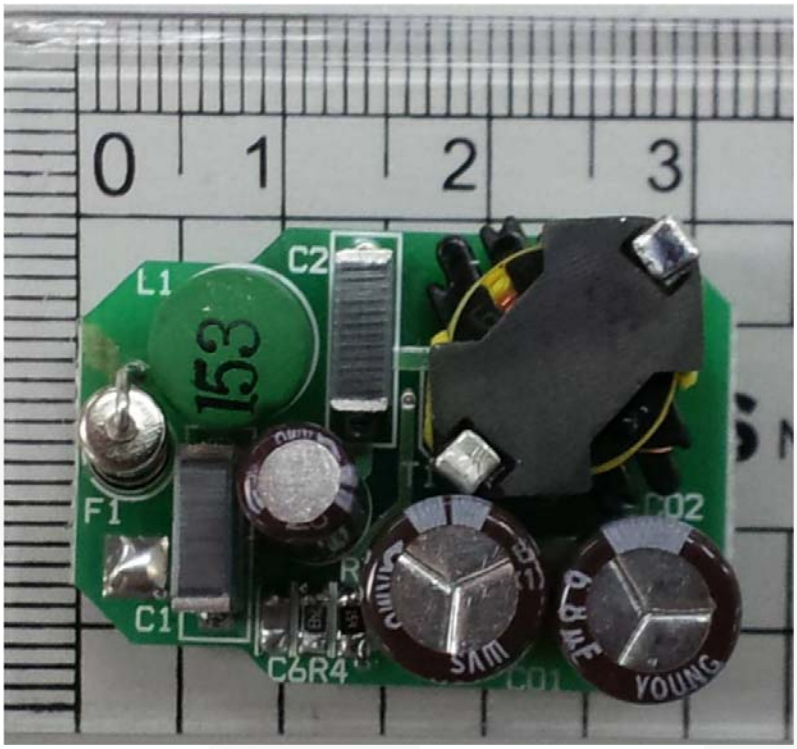

Figure 2. Top View

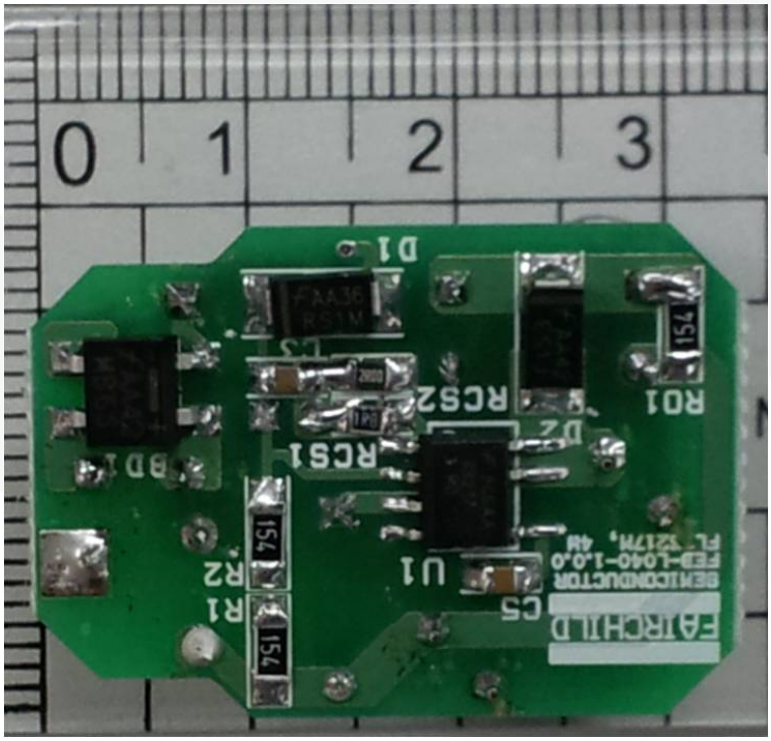

Figure 3. Bottom View

2.2. Printed Circuit Board

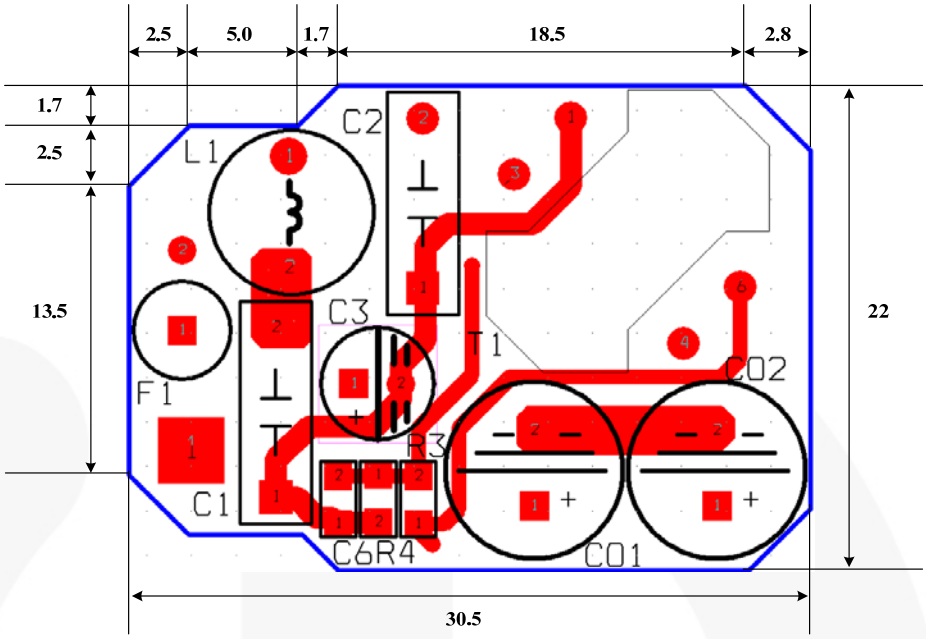

Figure 4. Top Side

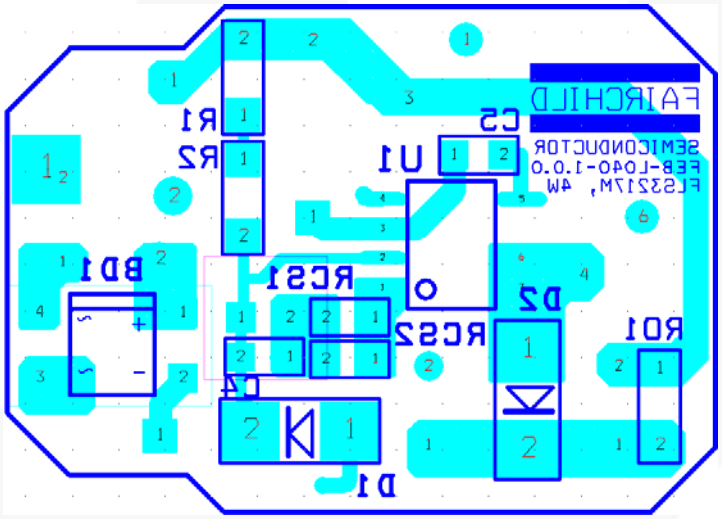

Figure 5. Bottom Side

2.3. Schematic

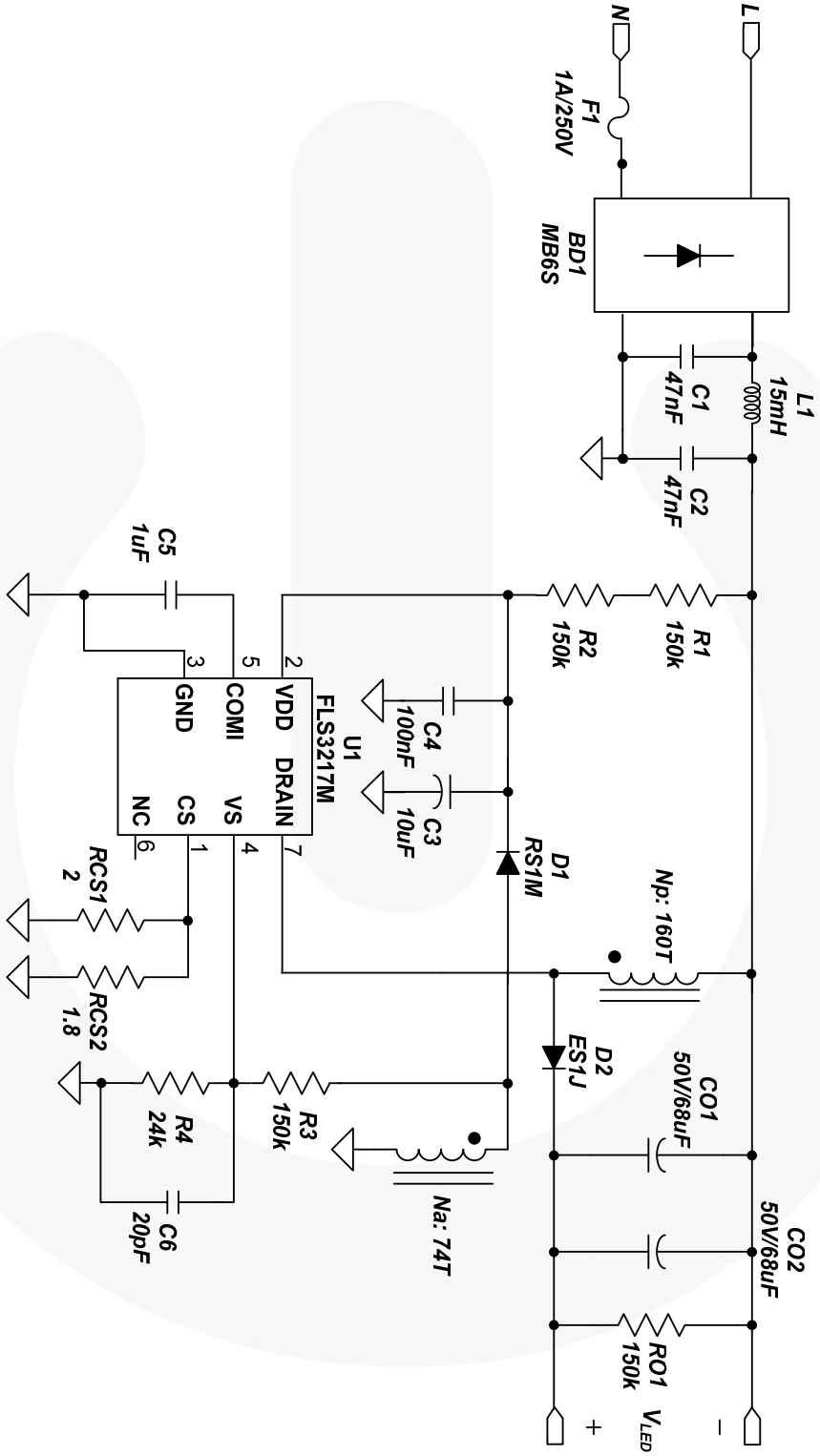

Figure 6. Evaluation Board Schematic

2.4. Bill of Materials

Item No.	Part Reference	Part Number	Qty.	Description	Manufacturer
1	BD1	MB6S	1	Bridge Diode	Fairchild Semiconductor
2	CO1, CO2	KMG 68µF / 50V	2	68µF / 50V, Electrolytic Capacitor	Samyoung
3	C1, C2	B32560J473K	2	473 / 400V, Film Capacitor	EPCOS
4	C3	KMG 10µF / 35V	1	10µF / 35V, Electrolytic Capacitor	Samyoung
5	C4	C0805C104K3RACTU	1	104 / 25V, SMD Capacitor 2012	Kemet
6	C5	C1206C105K3PACTU	1	105 / 25V, SMD Capacitor 2012	Kemet
7	C6	C0805C200M3GACTU	1	20pF / 25V, SMD Capacitor 2012	Kemet
8	D1	RS1M	1	1A / 1000V, Diode	Fairchild Semiconductor
9	D2	ES1J	1	1A / 600V, Fast Rectifier	Fairchild Semiconductor
10	F1	SS-5-1A	1	1A/250V, Fuse	Bussmann
11	L1	R06153KT00	1	15mH, 8Ø Filter Inductor	Bosung
12	R1, R2	RC1206JR-07150KL	2	150kΩ, SMD Resistor 3216	Yageo
13	RCS1	RC0805JR-072RL	2	2.0Ω, SMD Resistor 2012	Yageo
14	RCS2	RC0805JR-071R8L	2	1.8Ω, SMD Resistor 2012	Yageo
15	RO1	RC1206JR-07150KL	1	150kΩ, SMD Resistor 3216	Yageo
16	R3	RC0805JR-07150KL	1	150kΩ, SMD Resistor 2012	Yageo
17	R4	RC0805JR-0724KL	1	24kΩ, SMD Resistor 2012	Yageo
18	T1	RM6	1	Transformer	TDK
19	U1	FLS3217M	1	Main Driver	Fairchild Semiconductor

2.5. Transformer and Winding Specifications

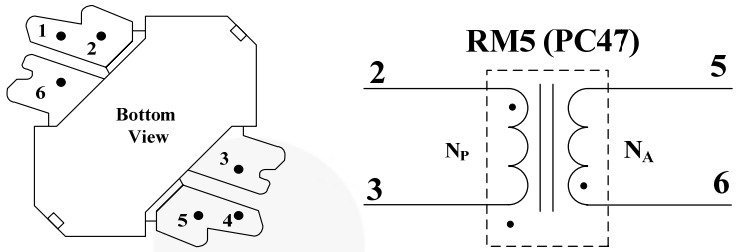

Figure 7. Transformer Bobbin Structure and Pin Configuration

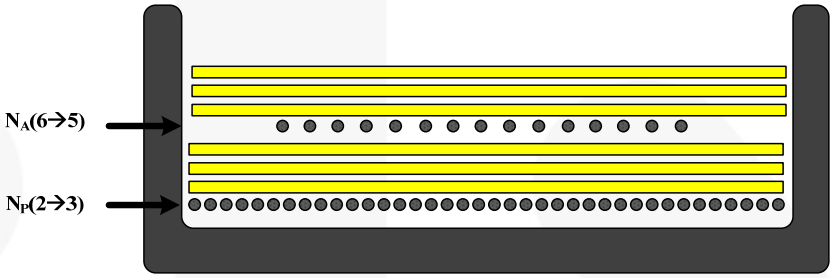

Figure 8. Transformer Winding Structure

Table 2. Winding Specifications

No.	Winding	Pin (S → F)	Wire	Turns	Winding Method
1	Np	2→ 3	0.15Ø	160Ts	Solenoid Winding
2	Insulation: Polyester Tape t = 0.025mm, 3-Layer				
3	Na	6→ 5	0.10Ø	74Ts	Solenoid Winding
4	Insulation: Polyester Tape t = 0.025mm, 3-Layer				

Table 3. Electrical Characteristics

	Pin	Specification	Remark
Inductance	2 – 3	2.0mH ±10%	60kHz, 1V
Leakage	2 - 3	30μH	60kHz, 1V Short All Output Pins

3. Performance of Evaluation Board

Table 4. Test Conditions & Equipment

Test Temperature	T_A=25°C
Test Equipment	AC Power Source: ES2000S by PSTATIONES Power Analyzer: DZ4000 by YOKOGAWA Electronic Load: PLZ303WH by KIKUSUI Automatic Power Tester: ATS3000 by BOB Multimeter: 2002 by KEITHLEY Oscilloscope: 104Xi by LeCroy EMI Test Receiver: ESCS30 by ROHDE & SCHWARZ Two-Line V-Network: ENV216 by ROHDE & SCHWARZ Thermometer: Therma CAM SC640 by FLIR SYSTEMS LED: EHP-AX08EL/GT01H-P01(1W) by Everlight

3.1. Startup Time

Test condition: connect 13 LEDs and measure the time interval between AC plug-in and stable output.

Table 5. Test Results

Input Voltage	Turn-On Time
90V_{AC} / 60Hz	840ms
115V_{AC} / 60Hz	660ms
230V_{AC} / 50Hz	270ms
265V_{AC} / 50Hz	239ms

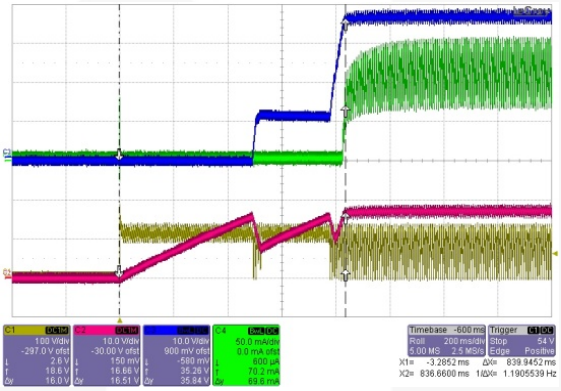

Figure 9. 90V_{AC} / 60Hz, C1 [V_{IN}], C2 [V_{DD}], C3 [V_{OUT}], C4 [I_{OUT}]

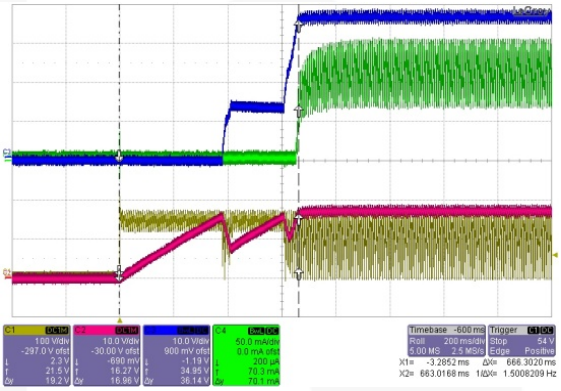

Figure 10. 115V_{AC} / 60Hz, C1 [V_{IN}], C2 [V_{DD}], C3 [V_{OUT}], C4 [I_{OUT}]

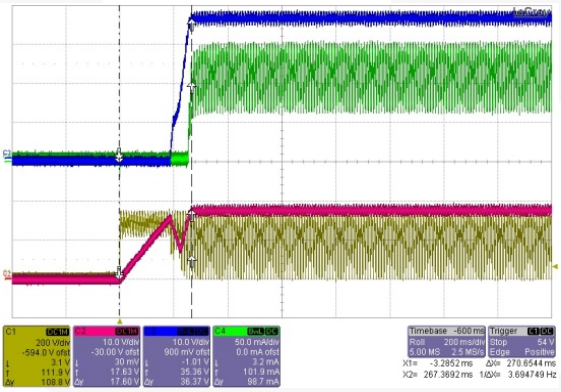

Figure 11. 230V_{AC} / 50Hz, C1 [V_{IN}], C2 [V_{DD}], C3 [V_{OUT}], C4 [I_{OUT}]

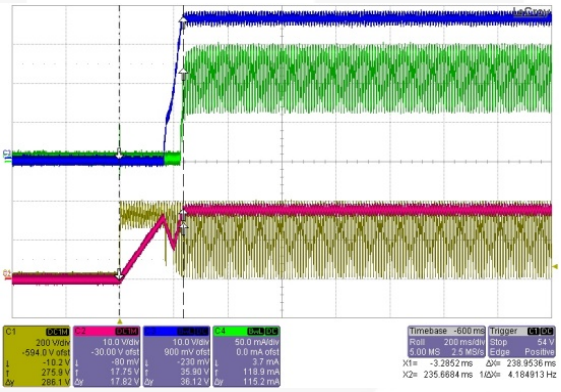

Figure 12. 265V_{AC} / 50Hz, C1 [V_{IN}], C2 [V_{DD}], C3 [V_{OUT}], C4 [I_{OUT}]

3.2. Output Ripple & Noise

Test condition: connect 13 LEDs.

Table 6. Test Results

Input Voltage	Current Ripple
$90V_{AC}$ / 60Hz	$96mA_{P-P}$
$115V_{AC}$ / 60Hz	$93mA_{P-P}$
$230V_{AC}$ / 50Hz	$94mA_{P-P}$
$265V_{AC}$ / 50Hz	$93mA_{P-P}$

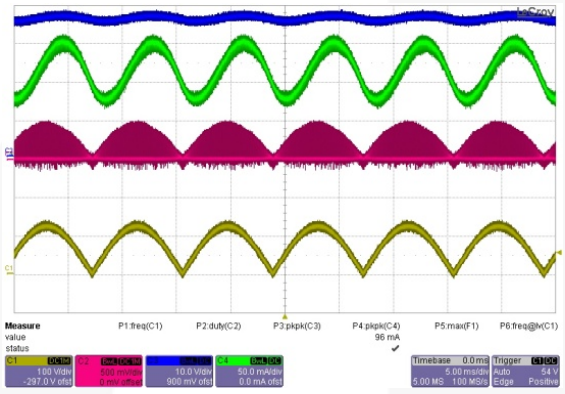

Figure 13. $90V_{AC}$ / 60Hz, C1 [V_{IN}], C2 [V_{CS}], C3 [V_{OUT}], C4 [I_{OUT}]

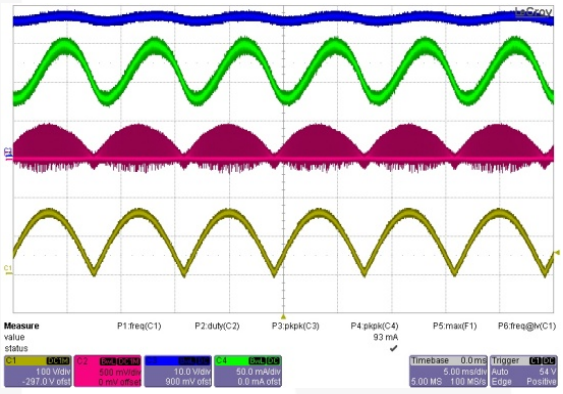

Figure 14. $115V_{AC}$ / 60Hz, C1 [V_{IN}], C2 [V_{CS}], C3 [V_{OUT}], C4 [I_{OUT}]

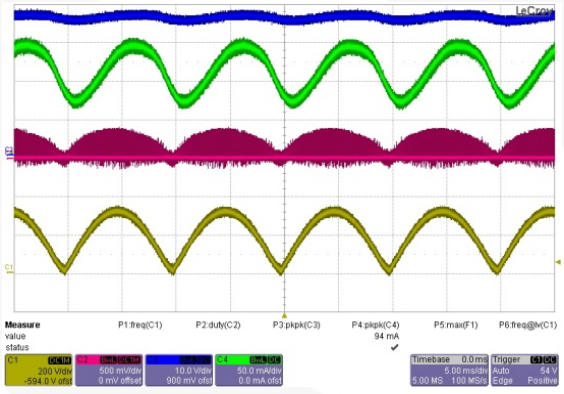

Figure 15. $230V_{AC}$ / 50Hz, C1 [V_{IN}], C2 [V_{CS}], C3 [V_{OUT}], C4 [I_{OUT}]

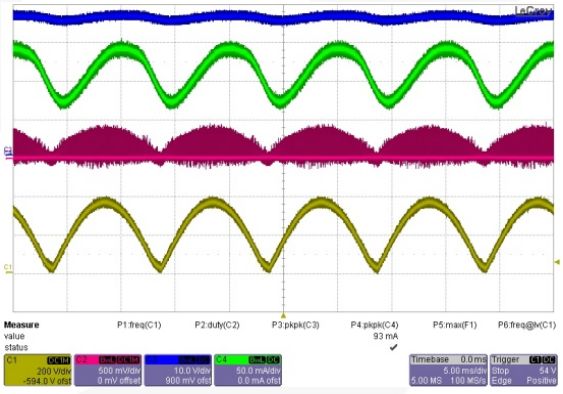

Figure 16. $265V_{AC}$ / 50Hz, C1 [V_{IN}], C2 [V_{CS}], C3 [V_{OUT}], C4 [I_{OUT}]

3.3. Short-LED Protection

Test condition: connect 13 LEDs. The output terminal is connected with GND after Power on. In short-LED condition, the OCP level is reduced from 0.7V to 0.2V because FLS3217 lowers the OCP level when V_S voltage is less than 0.4V during output diode conduction time.

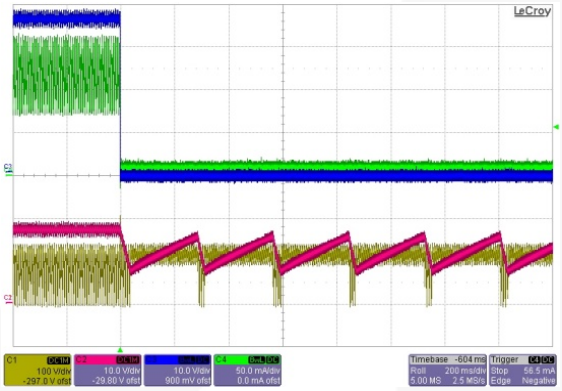

Figure 17. 90V_{AC} / 60Hz, C1 [V_{IN}], C2 [V_{DD}], C3 [V_{OUT}], C4 [I_{OUT}]

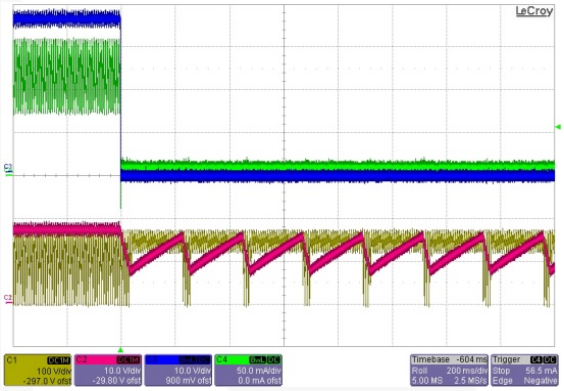

Figure 18. 115V_{AC} / 60Hz, C1 [V_{IN}], C2 [V_{DD}], C3 [V_{OUT}], C4 [I_{OUT}]

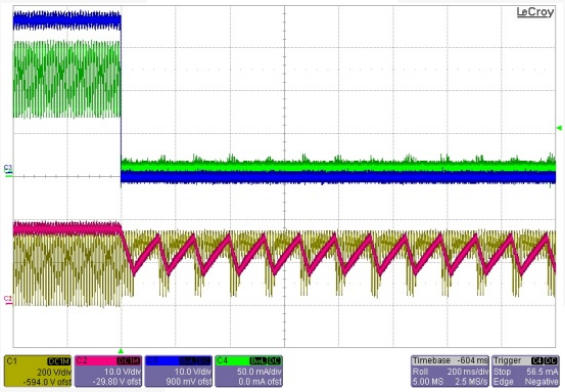

Figure 19. 230V_{AC} / 50Hz, C1 [V_{IN}], C2 [V_{DD}], C3 [V_{OUT}], C4 [I_{OUT}]

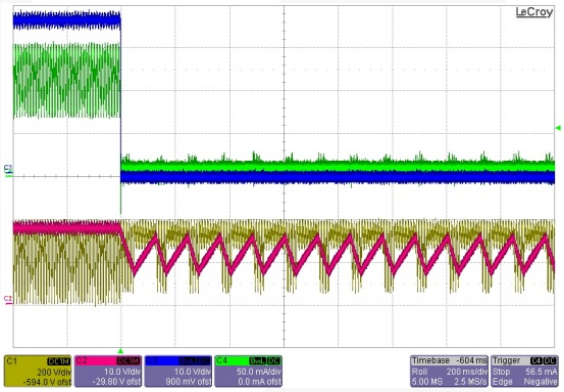

Figure 20. 265V_{AC} / 50Hz, C1 [V_{IN}], C2 [V_{DD}], C3 [V_{OUT}], C4 [I_{OUT}]

3.4. Open-LED Protection

Test condition: connect 13 LEDs. The output terminal is opened with LED after power on. In open-LED condition, the V_{DD} voltage increases to 22V because output voltage is increased. At that time, the FLS3217M initiate over-voltage protection.

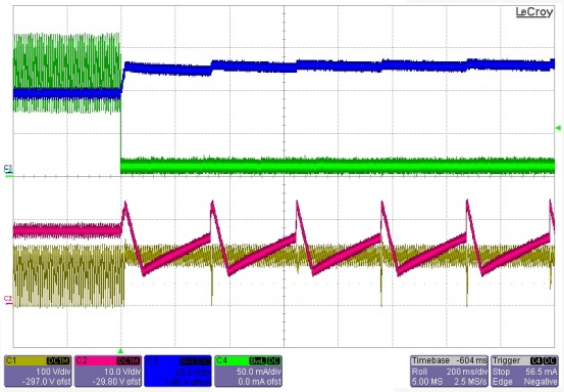

Figure 21. 90V_{AC} / 60Hz, C1 [V_{IN}], C2 [V_{DD}], C3 [V_{OUT}], C4 [I_{OUT}]

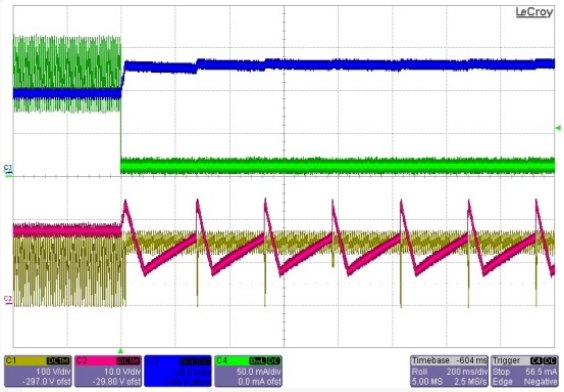

Figure 22. 115V_{AC} / 60Hz, C1 [V_{IN}], C2 [V_{DD}], C3 [V_{OUT}], C4 [I_{OUT}]

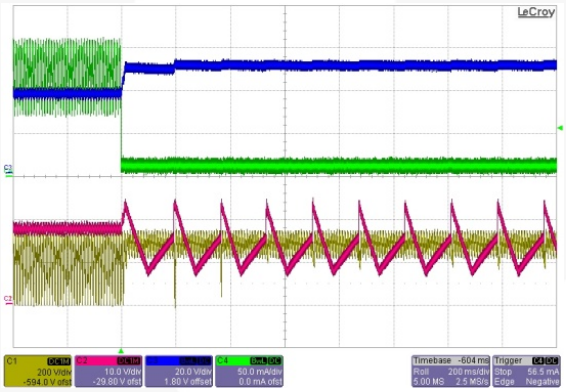

Figure 23. 230V_{AC} / 50Hz, C1 [V_{IN}], C2 [V_{DD}], C3 [V_{OUT}], C4 [I_{OUT}]

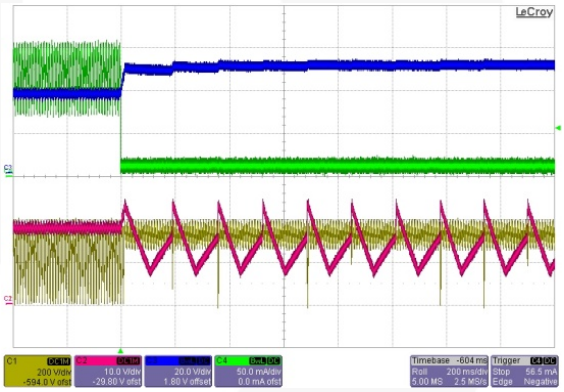

Figure 24. 265V_{AC} / 50Hz, C1 [V_{IN}], C2 [V_{DD}], C3 [V_{OUT}], C4 [I_{OUT}]

3.5. Constant Current Regulation

Constant current deviation in the wide output-voltage range from 7-LED (19.5V) to 13-LED (36.3V) is less than ±2.22% at each line input voltage. Line regulation is less than ±2.1%. The results were measured using LED load.

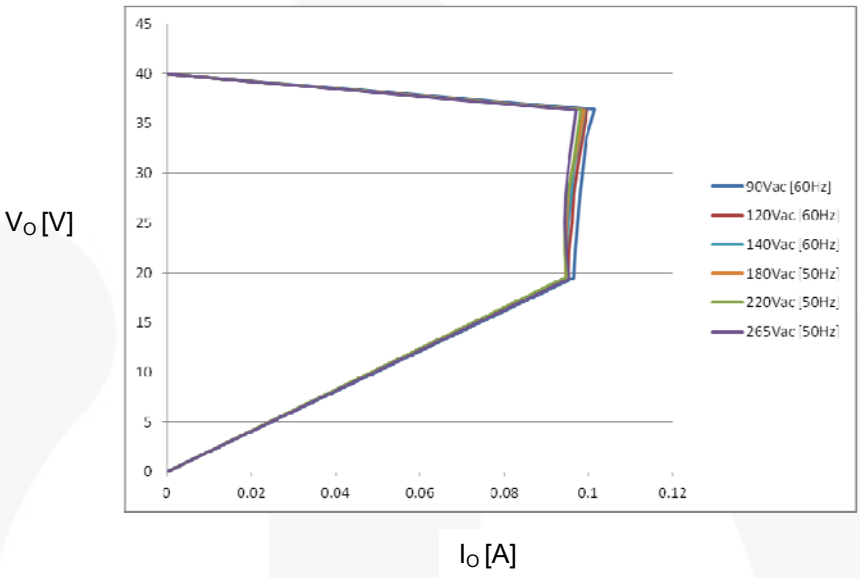

Figure 25. Constant Current Regulation – Measured 7-LED to 13-LED

Table 7. Constant Current Regulation by Output Voltage Change

Input Voltage	Min. Current [A]	Max. Current [A]	Tolerance
$90V_{AC}$ [60Hz]	0.097	0.102	±2.41%
$120V_{AC}$ [60Hz]	0.095	0.100	±2.16%
$140V_{AC}$ [60Hz]	0.095	0.099	±2.22%
$180V_{AC}$ [50Hz]	0.095	0.099	±2.18%
$220V_{AC}$ [50Hz]	0.094	0.098	±1.89%
$265V_{AC}$ [50Hz]	0.0.94	0.097	±1.44%

Table 8. Constant Current Regulation by Line Voltage Change

Output Voltage	$90V_{AC}$	$120V_{AC}$	$140V_{AC}$	$180V_{AC}$	$220V_{AC}$	$265V_{AC}$	Tolerance
36.3V	0.102A	0.100A	0.099A	0.099A	0.098A	0.097A	±2.17%
33.5V	0.100A	0.099A	0.098A	0.098A	0.097A	0.096A	±1.66%
30.7V	0.099A	0.098A	0.097A	0.096A	0.096A	0.095A	±1.77%

3.6. Efficiency

Test condition: connect 13 LEDs and measure the input and output power 30 minutes after aging.

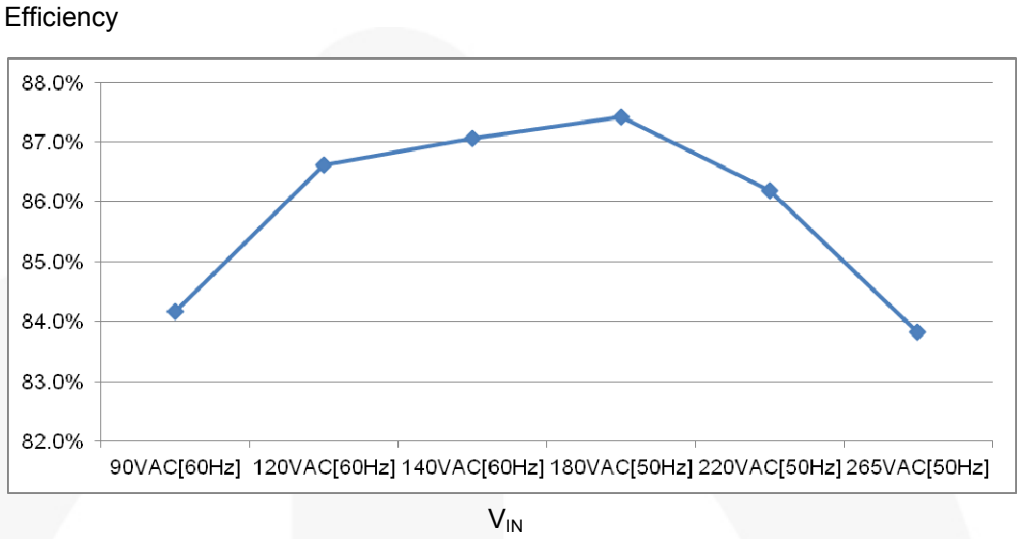

Figure 26. Efficiency Curve

Table 9. System Efficiency

Input Voltage	Input Power [W]	Output Current [A]	Output Voltage [V]	Output Power [W]	Efficiency
90V_{AC} [60Hz]	4.340	0.101	36.24	3.653	84.16%
120V_{AC} [60Hz]	4.180	0.100	36.2	3.621	86.62%
140V_{AC} [60Hz]	4.140	0.100	36.18	3.604	87.06%
180V_{AC} [50Hz]	4.140	0.100	36.17	3.619	87.42%
220V_{AC} [50Hz]	4.160	0.099	36.15	3.585	86.19%
265V_{AC} [50Hz]	4.210	0.098	36.12	3.529	83.81%

3.7. Power Factor & Total Harmonic Distortion

FLS3217 shows excellent Total Harmonic Distortion (THD) performance. THD is much less than 30% specification. Power factor also is very high with enough margin from 0.9. The results were measured 30 minutes after startup.

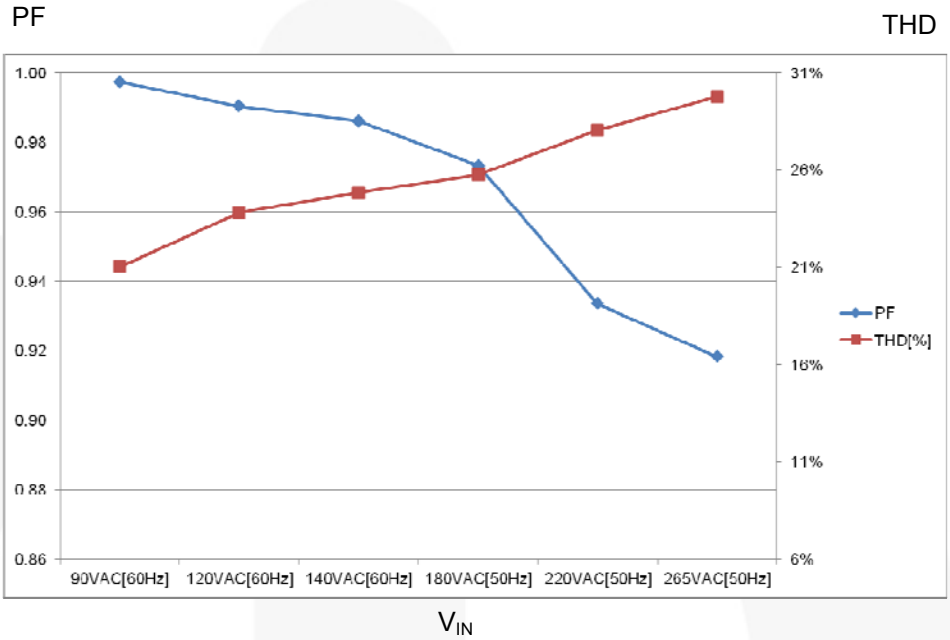

Figure 27. Efficiency Curve

Table 10. Power Factor & Total Harmonic Distortion

Input Voltage	PF	THD
$90V_{AC}$ [60Hz]	0.997	21.03%
$120V_{AC}$ [60Hz]	0.990	23.81%
$140V_{AC}$ [60Hz]	0.986	24.85%
$180V_{AC}$ [50Hz]	0.973	25.74%
$220V_{AC}$ [50Hz]	0.934	28.05%
$265V_{AC}$ [50Hz]	0.918	29.78%

3.8. Temperature

Test condition: connect 13 LEDs and measure the saturated temperature.

Table 11. Test Results

	90V_{AC} / 60Hz	265V_{AC} / 50Hz	Remark
FLS3217M	55.6°C	52.2°C	Bottom-Side Circle
Startup Resistors	47.9°C	55.3°C	Top-Side Box
Freewheeling Rectifier	47.4°C	45.3°C	Top-Side Spot
Transformer	51.3°C	49.9°C	Top-Side Box
EMI Inductor	46.7°C	53.2°C	Top-Side Circle

Temperature Photos

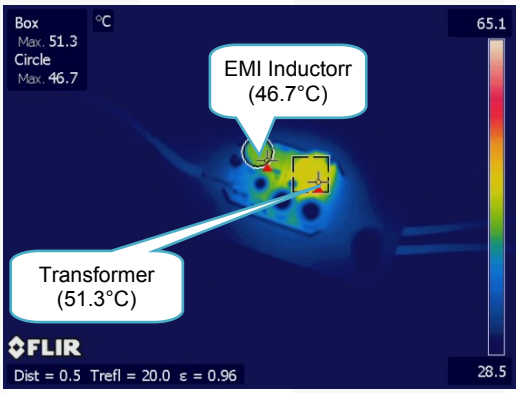

Figure 28. 90V_{AC} / 60Hz; Top-Side

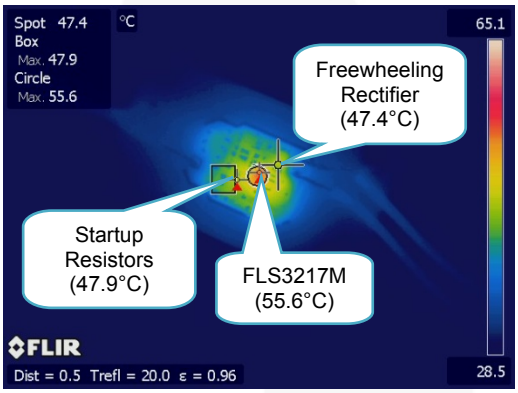

Figure 29. 90V_{AC} / 60Hz; Bottom-Side

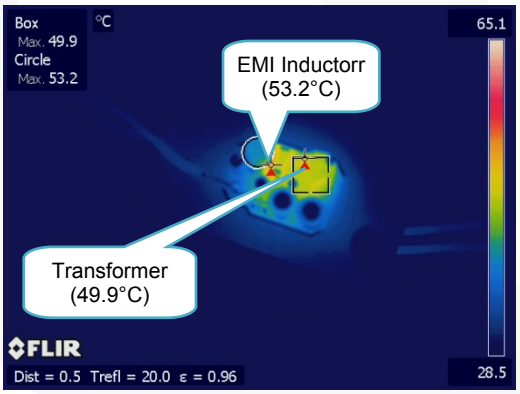

Figure 30. 265V_{AC} / 50Hz; Top-Side

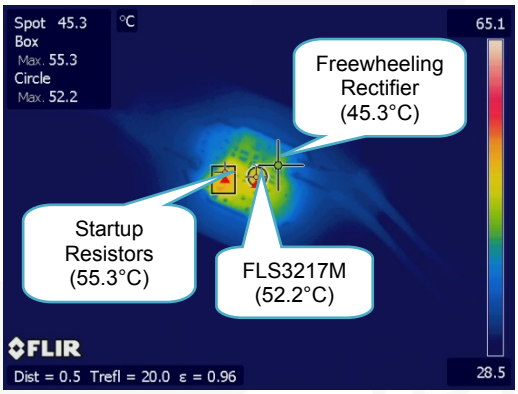

Figure 31. 265V_{AC} / 50Hz; Bottom-Side

3.1. Electromagnetic Interference (EMI)

Test Conditions:

- Frequency Sub-Range: 150kHz - 30MHz
- Measuring: QuasiPeak; Average
- Load: 13 LEDs

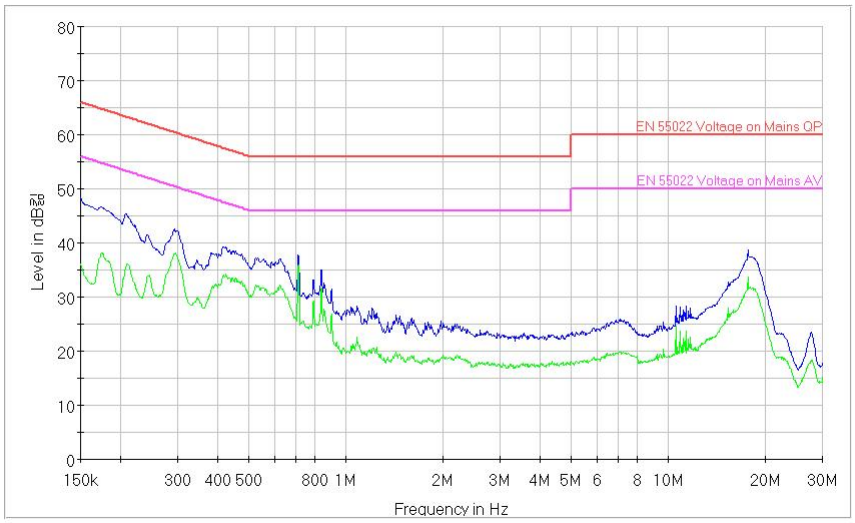

Figure 32. Conduction Line: 110V_{AC} / 60Hz

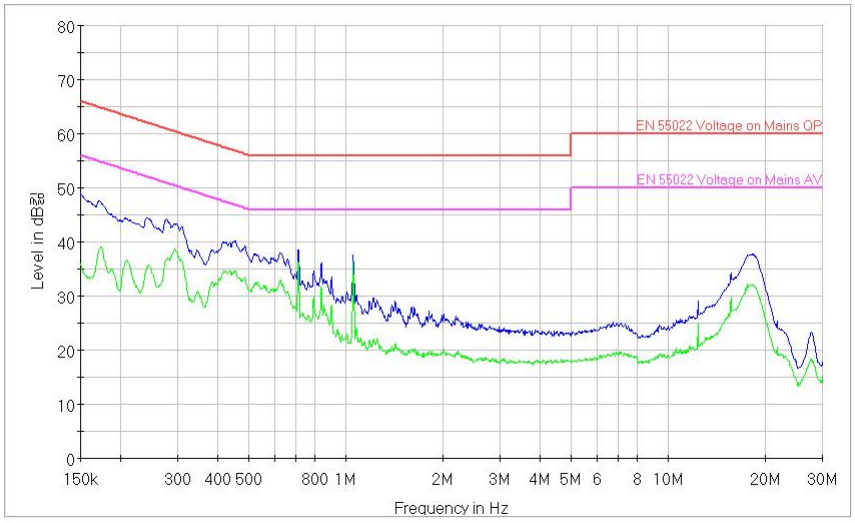

Figure 33. Conduction Neutral: 110V_{AC} / 60Hz

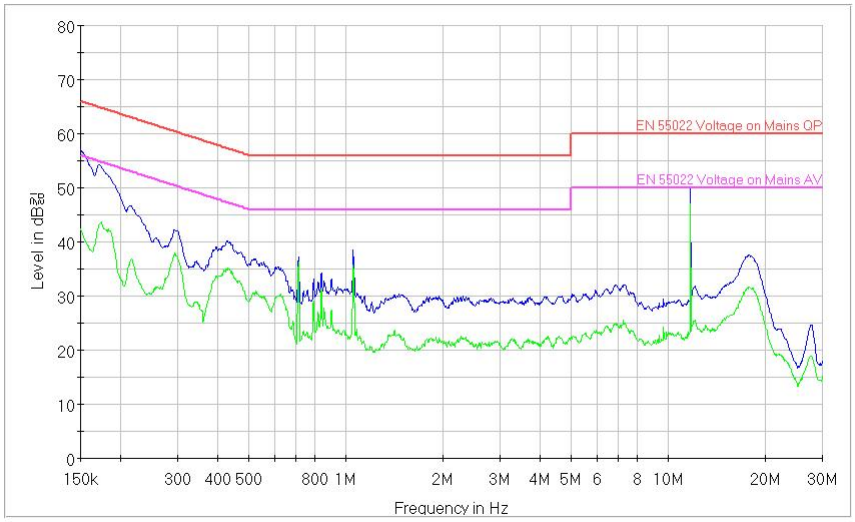

Figure 34. Conduction Line: 220V_{AC} / 60Hz

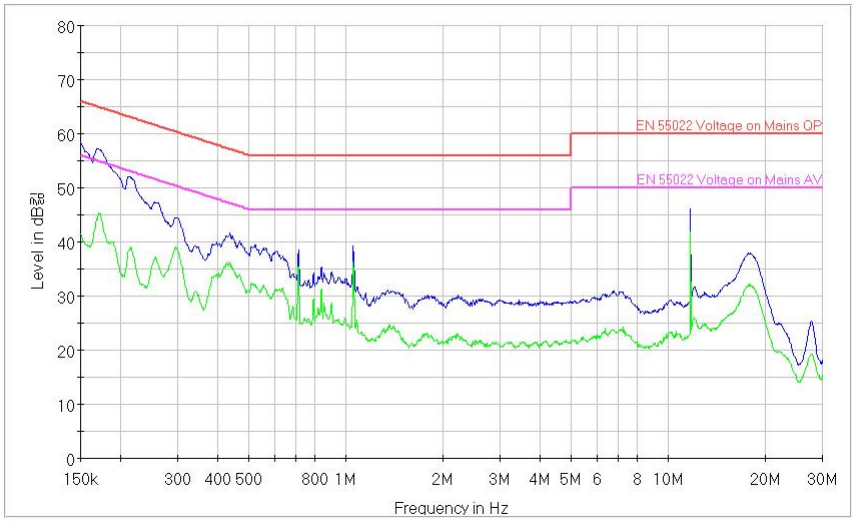

Figure 35. Conduction Neutral: 220V_{AC} / 60Hz

4. Revision History

Rev.	Date	Description
1.0.0	June 2011	Initial Release

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